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Heat waves reduce ecosystem carbon sink strength in a Eurasian meadow steppe

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ABSTRACT

Background: As a consequence of global change, intensity and frequency of extreme events such as heat waves (HW) have been increasing worldwide.
Methods: By using a combination of continuous 60-year meteorological and 6-year tower-based carbon dioxide (CO_2) flux measurements, we constructed a clear picture of a HWs effect on the dynamics of carbon, water, and vegetation on the Eurasian Songnen meadow steppe.
Results: The number of HWs in the Songnen meadow steppe began increasing since the 1980s and the rate of occurrence has advanced since the 2010s to higher than ever before. HWs can reduce the grassland carbon flux, while net ecosystem carbon exchange (NEE) will regularly fluctuate for 4–5 days during the HW before decreasing. However, ecosystem respiration (Re) and gross ecosystem production (GEP) decline from the beginning of the HW until the end, where Re and GEP will decrease 30% and 50%, respectively. When HWs last five days, water-use efficiency (WUE) will decrease by 26%, soil water content (SWC) by 30% and soil water potential (SWP) will increase by 38%. In addition, the soil temperature will still remain high after the HW although the air temperature will recover to its previous state.
Conclusions: HWs, as an extreme weather event, have increased during the last two decades in the Songnen meadow steppe. HWs will reduce the carbon flux of the steppe and will cause a sustained impact. Drought may be the main reason why HWs decrease carbon flux. At the later stages of or after a HW, the ecosystem usually lacks water and the soil becomes so hot and dry that it prevents roots from absorbing enough water to maintain their metabolism. This is the main reason why this grassland carbon exchange decreases during and after HWs.

1. Introduction

An increasing number of studies have shown that human activities and climate change have regulated ecosystems simultaneously, with human disturbances producing much stronger impacts than climate change (Chen et al., 2015a, 2015b). The fifth report of IPCC (2013) confirmed human activities contribute to extreme climate, such as heat waves (HWs) (Stocker et al., 2013). Compared to global warming, HWs have always done more damage to human societies and natural ecosystems, counteracting the global ecosystem and leading to more drastic climate changes (Ameye et al., 2012; Bauweraerts et al., 2013; Schubert et al., 2014). Therefore, HWs can be treated as a beginning of an ecosystem's vicious cycle. When we study this cycle, it is important to determine the impact of HWs on ecosystems.

The intensity and frequency of extreme climatic events such as HWs are increasing worldwide (Meehl and Tebaldi, 2004; Stocker et al., 2013). HWs are characterized by rapid heating for several days, having a much stronger influence on plants than gradual warming (Bauweraerts et al., 2013; Ciais et al., 2005; De Boeck et al., 2011; Meehl and Tebaldi, 2004). Unlike chronic warming,

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